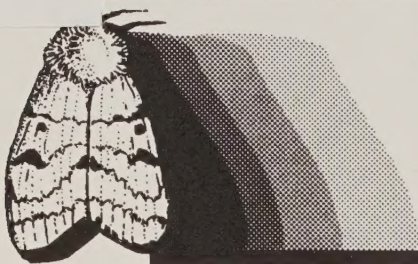


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# ***GYPSY MOTH NEWS***



United States  
Department of  
Agriculture  
Forest Service

**NORTHEASTERN AREA**  
*State and Private Forestry*



**July 1992  
Number 29**

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# **Technology Transfer Issue**

- The Swath Kit
- The Calibrator
- FSCBG

## **Plus ...**

**Egg mass sampling  
Asian Gypsy Moth  
Pheromones  
1992 Gypsy Moth Suppression Acreages**





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# LETTERS TO THE EDITOR

L. Tankersley, Agricultural Extension Service, Knoxville, TN, writes:

**"How are Dimilin and *B.t.* registered for use with such a 'paucity' of field data as implied in GYPSY MOTH NEWS, Issue No. 28 ?"**

Dr. J. W. Peacock, USDA Forest Service in Hamden, CT, responds:

Both of the pesticides, *B.t.* and Dimilin, are registered for control of forest pests, including gypsy moth, and both are marketed as "environmentally safe" materials--in terms of their direct effect on birds, fish, humans and other mammals. There is no question that both Dimilin and *B.t.* are efficacious in terms of their effect on the pest species against which they have been evaluated in field and laboratory studies. Concerning *B.t.*, it is registered against numerous forest and agricultural pests, including larvae of moths in the families Psychidae (bagworms), Tortricidae (tortricid moths), Geometridae (inchworm moths), Notodontidae (prominents), Arctiidae (tiger moths), Noctuidae (owlet moths), and Lymantriidae (tussock moths, including the gypsy moth). However, despite the considerable data available concerning the toxic effects of *B.t.* to pest species in these moth families, there have been few studies on the effects of *B.t.* on non-target species in these, or any other, families of Lepidoptera. Data from studies by Dr. Jeffrey Miller at Oregon State University, Drs. Linda Butler and Bradley Sample at West Virginia University, and from our own laboratory and field studies indicate that *B.t.* impacts certain native, non-target species of Lepidoptera. That is, larvae of several non-target species readily succumb after consuming *B.t.*-treated foliage in our laboratory assays, and the numbers of certain non-target species are reduced following aerial application of *B.t.* in field studies. Obviously, this impact could have negative short or long-term consequences for the non-target species themselves, and significant mortality to certain species could have an indirect effect on birds and other wildlife that rely on these non-target species for food. Field and laboratory studies currently in progress are aimed at

a better understanding of the short- and long-term impact of *B.t.* on native, non-target Lepidoptera.

Dr. Graham S. Thurston, University of California, writes:

**"Please don't cut your range maps at the U.S.-Canada border--it is so artificial. As a Canadian working in the United States, I am quite interested in the spread of the gypsy moth in Canada. Also, this information is of interest to ecologists (northern range expansion into a cold environment).**

The Editor responds:

Thanks for your suggestion. The Gypsy Moth News began as a Regional newsletter. Sometimes we forget our growing international scope and audience.

Dr. William H. Kearby, Wisconsin Department of Natural Resources, writes:

**"What success have you had with mass trapping 500 to 2,000 acres with 9 traps per acre?"**

Dr. Vic Mastro, USDA Gypsy Moth Methods Laboratory, Otis Air Force Base, MA, responds:

The largest area treated using only the mass trapping technique was in Appleton, Wisconsin. In the first year (1979), approximately 640 acres were treated with 3 traps per acre. Over the course of 3 years, a total of 1,120 acres were mass trapped. In the final year (1981), no males were captured. Through 1991, approximately 20 other isolated populations have been treated using only the mass trapping technique. Generally, treatment areas involved have been relatively small with acreage ranging from 5 to 200 acres. Often mass trapping has been used in combination with *B.t.* applications in eradication efforts. Determination or separation of the impacts of these two treatments cannot be made, however, the combination has been applied to at least 30 isolated sites successfully. The current recommendation trap density for mass trapping is 9 traps per acre. This recommendation is based on studies conducted with simulated known insect densities. The upper limit or absolute insect density, at which mass trapping



becomes ineffective as a control technique, is unknown.

Mr. Neil Forsyth, Commercial Horticultural Services, Vancouver, British Columbia, writes:

**"Can you send me a history of trap lures for the moth. Who invented this system - what year? What year did the Forest Service start to use trap lures? Does the Forest Service see this as an effective killing source?"**

The Editor responds:

I can tell you that as early as 1913, efforts to identify the chemical nature of the attractive materials emitted by female moths were initiated by the USDA. Collins and Potts (1932) reported on studies undertaken by the USDA in which arrangements were made for personnel from the Harvard Medical School and later from Harvard University to investigate the chemical nature of the attractant. Research continued for years by many people. Then in 1970, Bierl (see Bierl et al. 1970) announced that the pheromone had been chemically isolated and identified as cis-7,8-epoxy-2-methyloctadecane. The name "disparlure" was given to the material.

Disparlure is a behavior modifying chemical. The effectiveness of these chemicals in pest management depends greatly on the way in which they are formulated and released. Over the past 20 years, considerable research has taken place to improve the formulation and the trap within which it is placed. A good summary of these activities can be found in, "The Gypsy Moth: Research Toward Integrated Pest Management, 1981 (Doane and McManus, editors).

Since about 1930, traps baited with female moths or a sex attractant have been routinely used in support of a variety of containment, control, and regulatory programs. All of this early work was done in the Northeast United States in an attempt to contain or eradicate the moth. Since about 1972, systematic survey use of pheromone-baited traps has occurred over most of the U.S. and Canada where susceptible forest types occur. The purpose of this trapping program is to detect and delimit populations of gypsy moth remote from known infestations. Sometimes these captures are solitary moths spread presumably by man's activities and not indicative of an infestation; at other times subsequent scouting may

reveal an isolated or incipient infestation. Elimination or eradication of such an infestation is often desirable.

In addition to using disparlure in traps for detecting and delimiting gypsy moth infestations, it is also possible to use the traps following an insecticidal application. This procedure known as "mass trapping" is often used in conjunction with *B.t.* treatments for eradication purposes (see Mastro response to letter in this Issue).

Aside from the use of pheromones within traps as discussed above, disparlure has been used to disrupt chemical communications between the moth sexes. In this process, the broadcast application of the pheromone is used to thwart the normal process males use to locate females, thus disrupting mating. This control tactic, called mating disruption, is only effective in very sparse population densities of gypsy moth. Some recent work in this area was conducted by the USSDA Forest Service in Giles County, Virginia. Results are promising.

I hope that I have conveyed the importance of pheromone-baited traps as a survey tool. In addition, mass trapping and mating disruption techniques are used to control sparse populations. Pheromone traps and the use of the pheromone itself are not, however, usually thought of as "killing sources". Rather, the pheromone is used to confuse or modify the insect's behavior in such a way as to result in population reduction.

More information on this subject can be found in:

The Gypsy Moth: Research Toward Integrated Pest Management. 1981. C. Doane and M. McManus, editors. USDA Technical Bulletin 1584. Note that this compendium has an entire chapter devoted to pheromones and their use.

Bierl, B.A. et al. 1970. Potent sex attractant of the gypsy moth: Its isolation, identification, and synthesis. *Science* 170:87-89.

For information about the mating disruption use of pheromones in Giles County, Virginia, contact Richard Reardon, USDA Forest Service, 180 Canfield Street, Morgantown, WV 26505.



# THE SWATH KIT--A New Aircraft Characterization Tool

Amy Onken  
USDA Forest Service  
180 Canfield Street  
Morgantown, WV 26505

## Introduction

Each year, under the USDA Forest Service and Cooperative Suppression Programs, Federal, State, and County agencies aerially apply biological and chemical insecticides to approximately 1 million acres to control potentially defoliating populations of the gypsy moth. These programs utilize a variety of aircraft and spray systems.

In response to requests for a portable system to accurately characterize aircraft spray systems, the Forest Service, as part of its program to improve the aerial application of insecticides, entered into cooperative agreement with Penn State University to develop a portable system, THE SWATH KIT.

## Swath Kit Description

The SWATH KIT makes all the required weather, deposit measurements and swath pattern analyses on-site and displays the results in a timely manner.

The SWATH KIT is portable and can be operated from a car battery or a small portable generator. Its design is centered on a portable computer which centralizes much of the data processing and analysis, making the construction compact and operation simple.

Since production of the prototype model, significant hardware and software improvements have been made. The SWATH KIT has three components.

1. **Spray Trial Information and Weather Recording:** Spray trial parameters including aircraft and nozzle type and weather conditions are needed to interpret the deposit results. Data are typed into fields on a data input

screen. Each field has an on-line instruction which appears on the bottom of the screen to help identify the type of information needed and the acceptable numerical range.

When the trial information has been entered, the user moves to the weather recording screen. Weather sensing equipment automatically measures wind speed and direction, temperature and relative humidity and the computer records and updates this information every two seconds. The means and trends are shown graphically for data recorded over a ten-minute period (five minutes of data before and after the spray application). Weather data as well as a circular graphic showing the instantaneous wind direction relative to the collector line are presented visually to help the user make a go/no-go judgment on weather suitability prior to a pass over the deposit collectors (e.g. Kromekote cards). The SWATH KIT will relay warning messages when the wind direction is not perpendicular or parallel to the collectors depending on whether an "into the wind" or "crosswind" spray run is designated.

2. **Deposit Measurement:** A visible dye is added to the spray solution so that the image analyzer can distinguish individual droplets. Once the droplets are measured and data recorded for all collectors, a spray deposit profile is constructed.

The user selects the material sprayed from a menu of spray formulations and associated spread factors which are used in the calculation of the droplet size from the stain size. If the correct spread factor is not available, the collectors are read using an average spread factor provided in the menu. When the correct spread factor becomes available, the deposit data can be reprocessed by the computer without re-reading the collectors.

After the set-up is complete, the collector measuring begins. Starting with the first collector, and progressing in sequence, the computer prompts the user to hold a collector in front of the high resolution camera to make a measurement, then displays the results. For

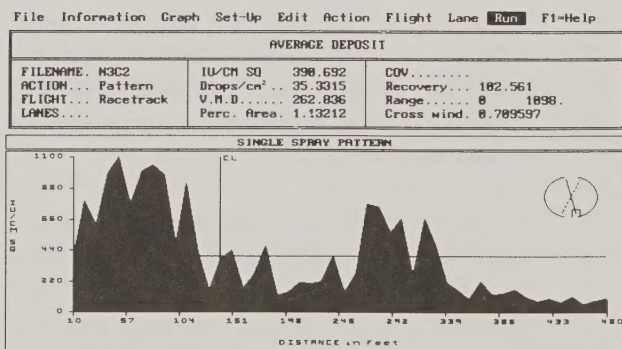


each deposit collector, the measurements can be completed in about 20 seconds. A full deposit pattern of 50 collectors can be analyzed in less than 30 minutes, depending on how many areas of each collector are sampled for each reading. In general, a minimum of four readings should be measured per collector. The image analyzer measures all droplet sizes, but graphically displays only droplets ranging from 23 to 600 microns. All droplet sizes are included in deposit calculations.

Deposit may be presented in several different ways: volume of spray per unit area, number of droplets per unit area, percentage of the surface area covered with spray, droplet size or all of these parameters.

3. Pattern Assessment (Figure 1): When the deposit on all of the collectors has been measured and the pattern of the deposit is assessed, the SWATH KIT displays a single pattern using any of the deposit parameters described above.

Summary statistics are also displayed.



**Figure 1.**

Problems in the pattern, such as the presence of peaks or valleys, assessment of the effective width of the pattern, and percent recovery of material can be detected and referenced to the spray trial data and weather recordings at this stage. The swath data can also be used to perform a lane separation analysis. This is a rapid way to investigate the effect of changes in lane separation on mean field deposit and the coefficient of variation. From this, you can quickly see the effects of badly judged spray runs

where lanes were flown too wide or too narrow. All data can be printed for a permanent record.

In August 1991, a modified version of an existing computer model called AGDISP (an aircraft swath pattern simulation model developed by Continuum Dynamics of Princeton, NJ) was added and can be run from the SWATH KIT software. AGDISP is a computer code that predicts, as a function of time, the motion of a group of similar sized particles or droplets released from an aircraft until it is deposited on the ground or in a canopy. This will enable modeled swath patterns to be compared with actual patterns obtained by aircraft configured in identical fashion. It is possible to run "what-if" scenarios on ways to improve a pattern by changing the numbers and location of atomizers. This allows a nozzle position problem to be resolved theoretically, and the aircraft re-configured accordingly, before being tested in the field.

## Technology Transfer

In July of 1990, a SWATH KIT Users Group and Newsletter were created. The Users Group is comprised of Federal, State, and County cooperators who depend upon the SWATH KIT to characterize aircraft spray systems that will be used in their gypsy moth suppression projects. The Newsletter keeps the users up-to-date on changes and modifications to the SWATH KIT's hardware and software. Also, reports from various operators on where and how the SWATH KIT is being used and trouble-shooting section that answers some questions and problems that arise while operating the Kit are included.

The information recorded during all spray trials involving the use of a SWATH KIT have been reviewed and stored by the USDA Forest Service in Morgantown, West Virginia. This database can be used like a "library" and is available to anyone who needs information concerning specific aircraft, nozzles, swath widths, etc. The database will be updated periodically and printouts for specific configurations are available.

If you have questions about the database or Users Group or would like more information on how to utilize the SWATH KIT, write to Amy Onken or call at (304)-285-1565.



# **CALIBRATOR--An Aircraft Calibration Tool**

**Stephen C. Smith and  
Daniel B. Twardus  
USDA Forest Service  
Forest Health Protection  
180 Canfield Street  
Morgantown, WV 26505**

Calibrator is software written for the TI-95 programmable calculator that turns the calculator into a spray aircraft calibration aid.

The aircraft calibration process is a string of formulae, factors, rates, and constants. Remembering it all, and knowing how and when to use these different numbers and equations is made easy when using the Calibrator. The Calibrator has the calibration process organized to guide the user through written menus and easy-to-understand prompts for information. For the novice, the Calibrator is an expert guide helping to organize the calibration process and accurately calculate answers. For the experienced, Calibrator is a tool to use to check calculations or solve complex calibration formulae.

Calibrator was created by Daniel B. Twardus and Stephen C. Smith, as a calibration tool that is:

1. easy to use
2. totally portable
3. a complete calibration package
4. fast and accurate
5. inexpensive

To use the Calibrator, basic information is entered--aircraft speed, swath, and rate of application. Calibrator calculates the expected flow rate. A nozzle type is selected--flat fans, hollow cones, becomists, and micronairs. Nozzle flow rates are preprogrammed within the Calibrator. For the conventional flat fan and hollow cone nozzles, Calibrator calculates the number of nozzles to install. For rotary atomizers, micronairs and becomist, the Calibrator optimizes settings. At any time, pressures and flow rates can be changed.

Calibrator has field checking routines for both conventional and rotary atomizers. Once the calibration is checked, the Calibrator recalculates number of nozzles or recalculates VRU settings. During field checking, the Calibrator checks actual calibration against expected to provide the user with a degree of accuracy.

The Calibrator has received considerable field testing over the past 2 years. As a package, it comes with the TI-95 calculator, an EPROM containing the software, and a handbook for self-instruction. If you would like additional information about the Calibrator, write to Dan Twardus or Steve Smith or call at (304)285-1545 or (304)285-1558, respectively.

# FSCBG AERIAL SPRAY MODEL

**Jack Barry**  
**USDA Forest Service**  
**2121C 2nd Street**  
**Davis, CA 95616**

FSCBG is a computer model that takes the near-wake aircraft results and predicts downwind deposition and dispersion considering the effects of evaporation, meteorology, canopy penetration, and ground and canopy deposition. FSCBG includes an evaporation model for volatile spray components, a canopy penetration model for forest canopy interception, a near-wake model for initial spray source distribution, and routines for atmospheric diffusion. Because mathematical spray dispersion models are useful in determining the interactions of the many factors affecting spray operations, the USDA Forest Service and its U.S. Army cooperator have supported the continuing development and application of these models. The enormous cost advantage of numerical simulation over field testing is obvious.

## Model Inputs

FSCBG takes input data entry from meteorological conditions, aircraft specifications, nozzle specifications, spray material information, canopy characteristics, and flight path.

1. Meteorological conditions anticipated during the spray mission (such as ambient temperature, relative humidity, wind speed and direction);
2. Aircraft information (including weight, wing span, flight speed, spray release height);
3. Nozzle information (number of nozzles, type of nozzle, locations on boom, flow rate of material through nozzles);
4. Spray material information (specific gravity, drop-size distribution, volatile fraction);
5. Canopy information (height of canopy, general shape, stand density; stems per acre); and

6. Mission scenario (number of aircraft passes, lane separation, length of these passes, flight direction).

Two data bases have been constructed to aid in the selection of inputs to FSCBG. An aircraft description data base contains specifications of 109 spray aircraft. A drop-size distribution data base contains 243 drop-size distributions from various nozzle types, flow rates, spray material, and aircraft speeds. This information flows into a series of calculations involving the above inputs.

The model is supported by several options to graphically plot deposition, dosage, and peak concentration in metric or English units.

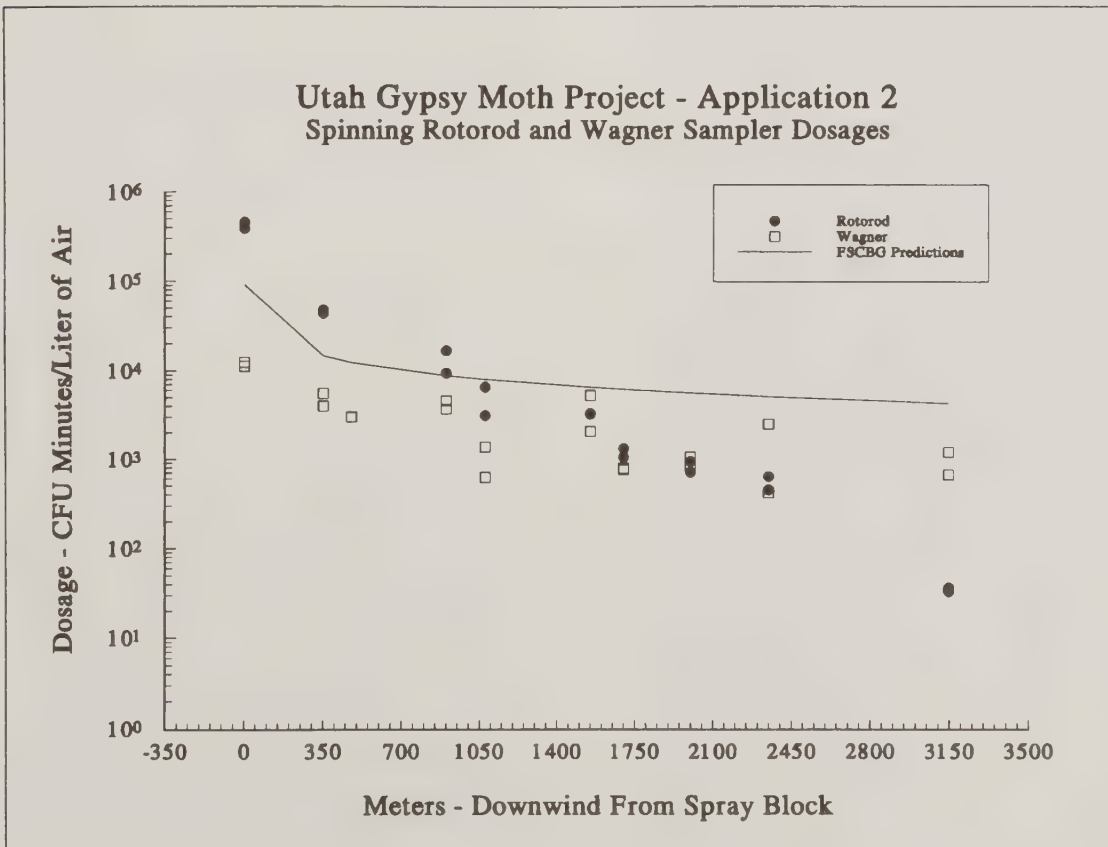
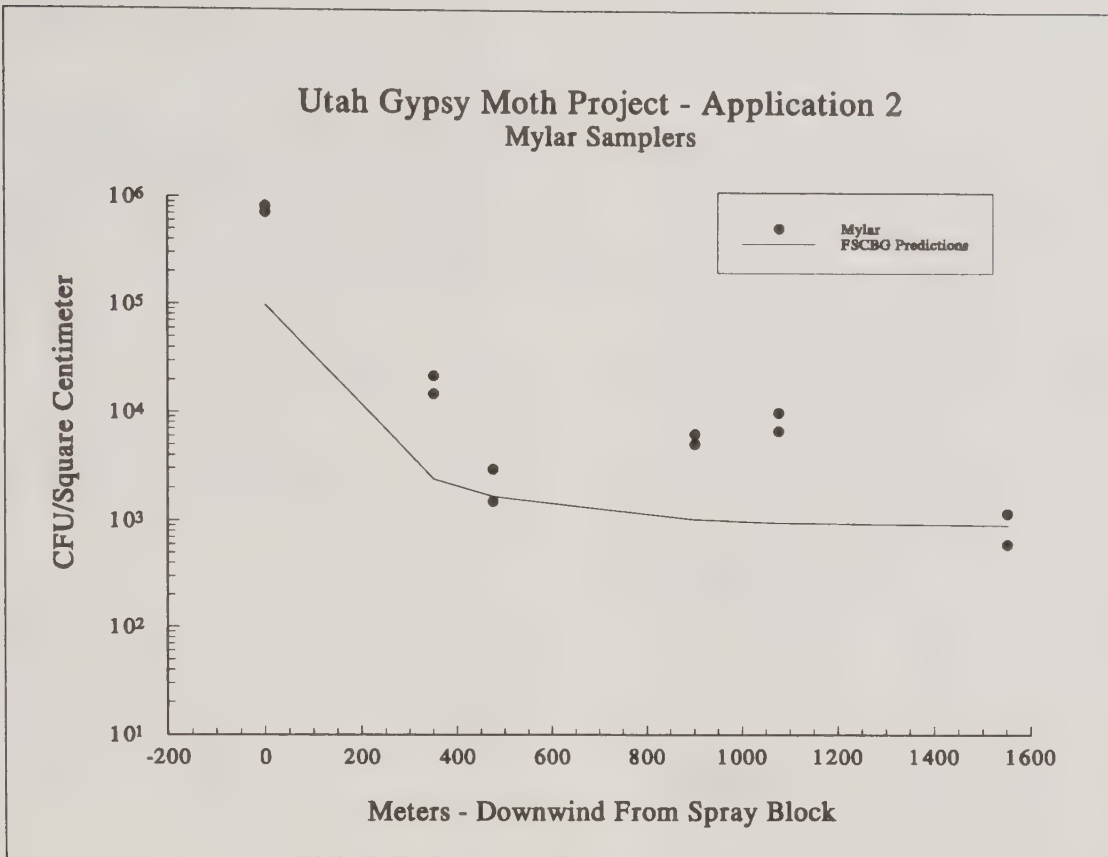
## Field Studies

Several field studies have been or are in progress to evaluate and improve FSCBG. Canopy/spray interaction studies are being conducted in the East, while canopy and drift studies are being conducted in the West. Data generated by these studies are being compared to FSCBG 4.0 predictions. Preliminary FSCBG data from the 1991 Utah gypsy moth project demonstrates the capability of FSCBG in predicting air dosage and deposition. Examples of the graphic plots with dosage and deposition expressed in colony forming units (CFU) are shown on the next page.

## Technology Transfer

The latest version of FSCBG is version 4.0. Membership in the FSCBG Users Group is represented by Federal and State agencies, universities, and the private sector. Model users include researchers, hazard assessment consulting firms, and organizations engaged in aerial application. The FSCBG Users Group, administered by Continuum Dynamics, Inc., P. O. Box 3073, Princeton, New Jersey 08540, (609)734-9282, under a Memorandum of Understanding with the USDA Forest Service, sponsors training, provides model operating code and updates, and distributes a newsletter, and user manual. The National Spray Model Advisory Committee, made up of scientists with interest in the model, meets annually to recommend development and evaluation activities and to coordinate their respective needs.





# ASIAN GYPSY MOTH IN THE PACIFIC NORTHWEST REGION

## United States

Dave Bridgwater, USDA Forest Service, Portland, Oregon, reports that during the summer and fall of 1991, one Asian Gypsy Moth (AGM) was trapped in Portland Oregon, and 9 around Tacoma, Washington. In response to these trap results, the USDA, Animal Plant Health Inspection Service formed a Western Regional Asian Gypsy Moth Project Team to deal with this introduction of a new pest. The Project Team is comprised of members from both Federal and State Agencies in the Pacific Northwest. In January, 1992, the Scientific Panel formed to advise the Project Team, recommended that about 8,000 acres in Portland and 114,000 acres in the Tacoma area be treated with *B.t.* three times to eradicate the AGM; and that intensive delimitation trapping be conducted during 1992 in the treatment areas and in a 20-mile wide buffer surrounding each treatment area. In addition, delimitation trapping was recommended in a 20 mile band around all other areas in the Pacific Northwest where AGM may also have been accidentally introduced, such as along shipping lanes in rivers or Puget Sound and other port areas.

An eradication program was developed. APHIS served as the Responsible Federal Agency and prepared the NEPA documentation, each State Department of Agriculture directed their respective portion of the eradication project, and the Forest Service prepared and awarded the aerial application contract and provided a Project Management Team.

The successful bidder on the aerial application project proposed using 20 application helicopters and 10 observation ships. The contract also required the bidder to supply the pesticide, and Foray 48B was the material chosen to be applied at 24 BIUs at 64 oz. per acre, undiluted.

The first treatment began on April 21, 1992 and the final application was completed on May 24. No

serious aircraft incidents or accidents occurred during the eradication project.

Local Citizens from Portland filed suit in U.S. District Court challenging the program on the basis of potential unknown health risks, and the necessity to treat such low population levels. The Court declined to enjoin the spraying.

Public interest concerning the eradication project remained high throughout the duration of the project. During the initial stages of the spraying, phone calls to the project headquarters totaled between 1,000 and 2,000 per day. By the end of the project, calls had dropped to 400 to 500 per day.

Intensive trapping in both the treatment areas and other potential introduction sites began in the middle of May. Results of the eradication project and locations of other potential infestations of AGM will not be known until after the traps have been collected at the end of September and any trapped moths have been identified.

## Canada

Peter Hall, with British Columbia Ministry of Forests reports that 18,000 hectares (ha) were treated in Vancouver, BC, to eradicate AGM infestations. Aerial spraying of Foray 48B at 50 BIU/ha was conducted using DC-6 aircraft plus one Bell 212. The application was repeated 3 times at 7- to 10-day intervals. Within the 18,000 ha area, 750 ha in Parksville and Collwood, both on Vancouver Island, were treated with a ground spray of *B.t.* at 50 BIU/ha. The Parksville and Collwood infestations were European gypsy moth. The project was conducted jointly by Agriculture Canada, and the Province represented by the Ministry of Forests. A steering committee guided the project's development. Jon Bell, Agriculture Canada, reports that the committee consisted of one representative each from Agriculture Canada, Forestry Canada, BC Agriculture, BC Forestry, and the City of Vancouver. Gordon Powell, Agriculture, Canada, was the overall project manager. The spraying took place under a Ministerial Order. A condition of this Order, however, required that a comprehensive health study be conducted. This study is being done by



Rick Mathias, University of BC, School of Public Health.

The project did not take place without some controversy. Agriculture Canada reports that over 30,000 telephone calls were handled during the project. A moth hotline was established just to answer public questions about the spraying. Media surveys indicated, however, that a majority of the citizens supported the eradication project.

Agriculture Canada is currently conducting a massive trapping program to evaluate results. Over a 2-year period, the estimated cost of this eradication program in Canada is \$6.2 million.

For more information about the eradication project in Vancouver, contact Jon Bell, Agriculture Canada, 202620 Royal Avenue, New Westminster, BC, V3L 5A8.

### THE ASIAN GYPSY MOTH

Three infestations of the Asian strain of the gypsy moth have been found in North America--two in the Pacific Northwest and one in Canada. The interest in AGM derives from the potential impact it could have upon our forests if it became established.

AGM susceptible hardwood trees and shrubs are present in every town in the West. Apple and other fruit trees are also favored hosts. In Russia, where AGM has consumed the foliage of its preferred host trees, it feeds on adjacent wheat fields.

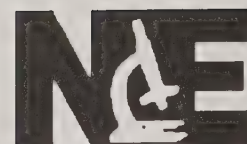
Studies show that AGM will be a more voracious feeder and thrive better on marginal hosts than the European gypsy moth; therefore, marginal hosts (which probably include Douglas-fir) become a concern. In Russia, AGM feeds on at least 600 plant species. Two examples of the many species that would be affected are western larch and Oregon white oak.

How did the AGM get here? Agriculture Canada reports having found egg masses and live larvae on ships which have docked at eastern Siberian ports during the egg laying period.

This area of Siberia is currently experiencing an AGM outbreak, and lights at the docks attract the egg laying female moths to the ships.

# GYPSY MOTH RESEARCH AND DEVELOPMENT PROGRAM

## Technology Update



NORTHEASTERN FOREST  
EXPERIMENT STATION

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### New Approaches to Sampling for Decision Making

**Andrew Liebhold**  
**USDA Forest Service**  
**Northeastern Forest Experiment Station**  
**180 Canfield Street**  
**Morgantown, WV 26505**

Every year, about a million acres of forest are sprayed, as part of the USDA Forest Service Co-operative Suppression Program and other programs that are designed to reduce or prevent the impacts of defoliation by the gypsy moth. Specific procedures vary among the States and agencies that participate in these programs, but nearly all of the programs within the generally infested area rely on preseason counts of egg masses in order to evaluate the necessity of treating stands.

A variety of procedures exist for counting egg masses. The most commonly used method is the use of multiple-fixed-radius plots (typically 1/40th acre) (Kolodny-Hirsch 1986). In this method, a number of replicated plots are distributed through-out the woodlot. The "five-minute walk" was a technique developed to estimate egg mass density using less labor (Eggen & Abrahamson 1983). Under this method, observers simply walked through the stand and kept count of all visible egg masses. Eggen and Abrahamson (1983) presented an algorithm for converting these counts into the more conventional expression of density as egg masses per acre.

Recently, Liebhold et al. (1991) and Fleischer et al. (1991) found that the five-minute walk was subject to bias and did not provide estimates with an adequate level of precision.

How good of a job are we doing? Using these procedures, do managers generally make good predictions about defoliation and consequently make good treatment decisions? Unfortunately, we do not have an exact answer to these questions, but evidence suggests that decision errors are in fact common. Many stands where preseason egg mass counts indicate no defoliation will occur, and treatment is therefore unnecessary, end up getting defoliated. Conversely, many stands where preseason egg mass counts indicated defoliation will occur, may not become defoliated even if they were not treated. An unpublished study by the Pennsylvania Department of Environmental Resources indicated that as many as 50 percent of treated blocks may not have been defoliated had they not been sprayed (PA Bur. of Forestry, 1990). There are probably two reasons for these errors: 1) measurement error that occurs from taking relatively few egg mass samples from a heterogeneously distributed population, and 2) intrinsic error about the relationship between the true preseason egg mass density and subsequent defoliation. Mitigating this problem will entail dealing with both of these problems.

### Sampling Error

Given the financial constraints of most gypsy moth management programs, it is difficult to avoid considerable sampling error. For example, in a hypothetical program, 5 fixed-radius plots may be used to estimate egg mass density in a 500-acre proposed spray block. Under this scenario, only



0.025 percent of the area is actually sampled. The low intensity of sampling, along with considerable heterogeneity of egg mass population densities results in a very high sampling error. Given the above sampling intensity, it is not uncommon for the standard error of the estimate to be roughly 50 percent of the mean. This indicates, for example, that when we estimate a population density of 1,000 egg mass per acre, all we can say is that 95 percent of the time the true density is somewhere between 0 and 2,000 egg masses per acre! Kolodny-Hirsch (1986) and Fleischer et al. (1991) developed sequential sampling schemes that allow managers to control the error in egg mass density estimates relative to treatment threshold densities. Under these plans, if estimates are considerably above or below the density threshold, then sampling can be terminated. However, when estimates are near the thresholds, many more samples will need to be taken.

There is clearly a need to develop new ways of sampling egg mass densities that do not require so much time. The five-minute walk was developed as a way of rapidly quantifying egg mass densities over large areas. Unfortunately, it is prone to observer bias and provides density estimates that are less precise than those derived from investing the same amount of labor into fixed-radius plots; even one fixed-radius plot provides a more precise density estimate than four 5-minute walks (Liebhold et al. 1991, Fleischer et al. 1991). Therefore, the use of five-minute walks should be discontinued.

### Density-Defoliation Relationship

Most of the egg mass density thresholds that are used for treatment decision-making are based upon the correlation between density and defoliation. Several groups have taken field data from untreated plots and related density estimates to subsequent defoliation levels and then fit equations to these data (Gansner et al. 1985, Campbell 1966, Williams et al. 1991, Montgomery 1990). The problem that is encountered in using these equations is that the actual fit to the data is often quite poor (see Figure 1). Of course, part of the reason for the poor fit is sampling error in the estimates of density and defoliation but even when relatively large numbers of plots are used to estimate density and defoliation (12 fixed-radius plots were used to calculate each point on Figure 1), the relationship is still quite "loose". The problem is

most acute for stands where preseason egg mass counts vary between 100 and 1,000 egg masses per acre; through this range in densities, defoliation ranges from 0 to 100 percent and there appears to be little relationship between density and defoliation.

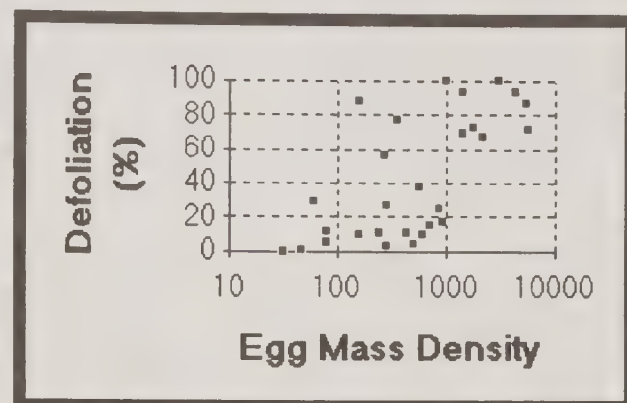


Figure 1. Relationship between preseason egg mass density estimates and subsequent defoliation in 25 acre woodlots in south-central Pennsylvania (from Liebhold et al., unpublished).

There are several biological reasons for variation about the egg mass density-defoliation relationship. For example, the number of larvae that hatch per egg mass is often quite variable. This, in turn, may reflect variation in fecundity (number of eggs per mass), egg viability, and parasitism (Moore & Jones 1987). Furthermore, many things can happen between the time of hatch and the late-larval period when peak defoliation typically occurs. Large numbers of 1st instars may immigrate from adjoining stands, or populations may collapse as a result of disease or starvation (Elkinton & Liebhold 1990). Recently there has been renewed interest in identifying variables other than egg mass density that might provide more precise forecasts of defoliation (Montgomery 1989, Liebhold et al. unpublished). These other variables include estimates of fecundity, egg mass size, density in the previous generation, and counts of old egg masses. Results to date indicate that collection of certain additional field measurements can increase the precision of defoliation predictions, but this increase in precision is only slight.

## Outlook for the future

Because of the difficulty in obtaining adequate numbers of samples and because of the intrinsically variable relationship between measures of egg mass density (and other stand-level measurements) to defoliation, we may never be able to predict defoliation with an adequate level of precision from stand-level data alone. The most attractive solution to this problem in the future may be to utilize regional population data in addition to stand-level data.

Twenty-five years ago, Campbell (1967) recognized that the dynamics of gypsy moth populations are affected by population conditions in nearby areas; there is often considerable synchronism in yearly fluctuations in the development of gypsy moth outbreaks (Liebhold & McManus 1991). Typically populations seem to rise and fall in synchrony over large regions, probably as a result of similar weather effects on population processes. Though astute managers take advantage of information on regional conditions and population trends, this procedure is rarely formalized in the decision-making process. In the future, information from these regional monitoring systems can be used, along with stand-level information as a method for improving our defoliation predictions.

Gage et al. (1990) used a geographical information system (GIS) to develop models for predicting pheromone trap catch from trap catch in previous years and demonstrated how trap capture maps were related to defoliation maps. Presumably, a similar approach that uses egg mass counts instead of pheromone trap capture data would be possible. Hohn et al. (unpublished) have developed a geostatistical model that forecasts probabilities of future gypsy moth defoliation from historical spatial patterns of defoliation in the same area; this model quantifies the temporal persistence and spread of defoliation in a predictive model. Ultimately, these two approaches will probably be married in models that predict maps of regional probabilities of defoliation using both historical defoliation maps, forest type maps, and networks of permanent census plots.

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## 1992 Cooperative North American Gypsy Moth Spray Projects in Acres

State	Ownership	Dimilin	B.t.	Gypchek	Total
Delaware	State Cooperative	17,280	19,375	0	36,655
Georgia	Eradication	0	5,250*	0	5,250
Massachusetts	State Cooperative	0	2,685	0	2,685
Maryland	State Cooperative	24,778	58,676	0	83,454
	Other Federal	0	5,985*	230*	6,215
Michigan	State Cooperative	0	255,301	0	255,301
	National Forest	0	2,299	0	2,299
North Carolina	State Cooperative	0	6,688	0	6,688
	Eradication	1,000*	1,406*	0	2,406
New Jersey	State Cooperative	0	25,192	0	25,192
Ohio	State Cooperative	3,901	1,610	0	5,511
Pennsylvania	State Cooperative	85,121	119,640	0	204,761
	National Forest	0	23,133*	0	23,133
	Other Federal	0	967	0	967
Tennessee	Eradication	1,000*	2,000*	0	3,000
Utah	National Forest	0	15,718**	0	15,718
Virginia	State Cooperative	64,264	43,185	0	107,449
	AIPM	40,060	49,350	2,497*	91,907
	Eradication	0	5,280	0	5,280
	National Forest	0	960	0	960
	Other Federal	8,678	2,475*	353*	11,506
Wisconsin	Eradication	0	40,853**	0	40,853
West Virginia	State Cooperative	26,516	3,408	0	29,924
	AIPM	18,066	49,551	4,200***	71,817
	Eradication	0	2,024	0	2,024
Total		290,664	743,011	7,280	1,040,955

\*Includes double applications on some or all of these acres.

\*\*Includes triple applications on some or all of these acres.

\*\*\*Includes 3,730 acres of pheromone flakes and 470 acres of Gypchek.

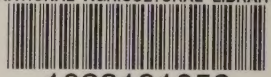
NOTE: Data obtained from the National Pest Suppression Tracking System (revised 06/30/92).

## 1992 Cooperative Asian Gypsy Moth Spray Projects in Acres

State	Ownership	Dimilin	B.t.	Gypchek	Total
Oregon	Eradication	0	124,846*	0	124,846
Canada**	Eradication	0	44,478*	0	44,477
Total		0	169,324	0	169,323

\*Includes triple applications on some or all of these acres.

\*\*Data obtained from British Columbia Ministry of Forests.



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